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A Novel Design and Implementation of a Smart Glove for Arabic SLR System Based on the Statistical Analysis of the Arabic Sign Language

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Abstract : There are more than 10 million deaf people in the Arab nations presently—Egypt alone accounts for 4 million deaf people. Hence, an Arabic sign language is necessary for facilitating communication between the hearing-impaired people and the larger society. However, everyone does not understand this language. Furthermore, the previous systems were designed for SLR, which were extremely expensive, and several sensors were required to interpret all hand and finger motions. For these reasons, a new prototype of the smart glove is produced, which can be used as a part of an electronic system to translate the Arabic sign language into a spoken or written Arabic. This design includes all Arabic sign language signs (words level) by using 4-flex sensors, 4-contact pad sensor, gyroscope, and accelerometer, controller, and Bluetooth Module per hand. The design is driven from a statistical analysis of the Arabic sign language – 1300 words in terms of single hand signs, double hand signs, single-stage signs, multi-stage signs, fingers angle, and orientation. This paper explores the design analysis and implementation of this system. The result of the (53words) samples of Arabic SL signs (involving all classification) is 85% pass from the first time and 15% pass after many trials (double-hand multi-stage signs classification) due to the synchronisation problem of the two hands data. The system is low cost, requires low power, and has a fast response.

Keywords: sign language, smart gloves, embedded system, Arabic SLR, deaf people.

1. INTRODUCTION

As per the latest survey conducted by the Central Agency for Public Mobilization and Statistics, the number of deaf people in Egypt stood at 4 million. 70% of them of them don't know reading and writing the Arabic language. This community is unable to communicate with natural hearing. They suffer from legal, religious, moral and social illiteracy. This disconnection creates frustration and congestion that may push them to commit crimes against their community [1]. Sign language is not a common language between all deaf people. Like other languages, these vary from society to another society. They are not completely based on the spoken language in the country of origin Sign language is a visual language and there are 3 major Components of this language: [1-5]

1- Letter level: used to spell words letter by letter.
2- Word level: used to spell the sentences word by word
3- Expression level: facial expressions and tongue, mouth and body position.

Two approaches have traditionally been used in the literature: image processing-based systems and electronic gloves-based system [6]. Electronic gloves - based system requires the user to wear electronic gloves while performing the signs, also this system includes different types of sensors for detecting different hand and finger articulations. But Image processing-based system uses a camera(s) to acquire a sequence of images of the hand. Each of the two approaches has its own cons. The electronic gloves-based method is not natural as the user must wear a cumbersome instrument, on the other side the image processing-based system requires specific background and environmental conditions to achieve high accuracy.by comparing the two systems, Components of image processing-based is more cost than the electronic gloves-based method. The statistical analysis of Arabic SL which was done by the authors in previous studies for (1300 words), which is analysed as shown in Table 1(i.e. as a sample), and the design is simulated by using electronic simulation software [7]. For these reasons which are mentioned, the electronic gloves- based method was used in this study [8].

Table 1: Samples of Sign Language Analysis

num	words	RIGHT HAND													LEFT HAND												
		thumb	index	middlef	ring	pinky	palm	OTI	OIM	OMR	ORP	OOP	MOT	stage	thumb	indext	middle	ring	pinky	palm	OTI	OIM	OMR	ORP	OOP	MOT	stage
1	حرف - أ	1	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	حرف - ب	1	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	حرف - ت	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	حرف - ث	1	1	1	1	1	0	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
5	حرف - ج	1	1	1	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6	حرف - ح	1	1	1	1	1	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
7	حرف - خ	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

2. THE DESIGN OF SMART GLOVES DEPENDING ON THE ARABIC SL STATISTICS

Depending on previous studies of ARSL statistical analysis which was built according to the anatomical shape of the hand, it can be Suggested a new low-cost simple design with 6-flex sensors are used to detect the motion of fingers and motion of palm, 4-contact pad sensors are used to detect the orientation of fingers, 3-axis Gyroscope and Accelerometer are used to detect the orientation of hand relative to the body, and Microcontroller is used to collect the sensors data and transmit it to the central node (i.e. Computer). Finally, the computer will be used in conjunction with a certain searching algorithm to estimate the actual word relative to the sign. Fig.1 illustrates the distribution of two hand sensors.

The complete system is designed as a block diagram showing in Fig.2. Six analog input pins are needed to interface the flex sensors (length of sensor= 5cm) with the controller, four digital inputs pins are needed to interface contact pad sensors, two pins are needed to interface with Bluetooth module (HC-05) by using UART protocol, two pins to interface with gyroscope and accelerometer module (MPU-6050) by using I2C protocol.

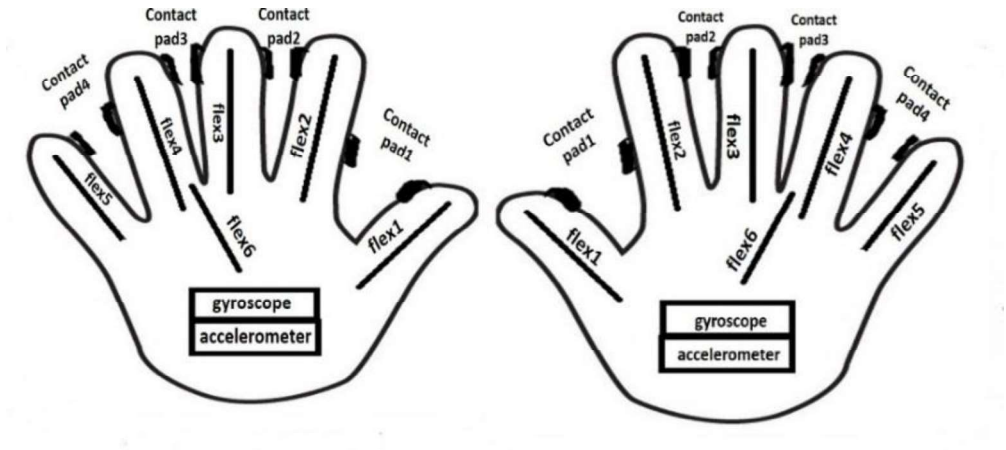


FIGURE 1. Right and Left Hand Sensors Distribution

TABLE 2: Cost of Components of the Glove

Item	MPU-6050	HC-05	Flex sensor	Contact Pad	glove	Arduino	Interface circuit	Total
Price	10$	8$	5$	1$	5$	26$	10$	65$

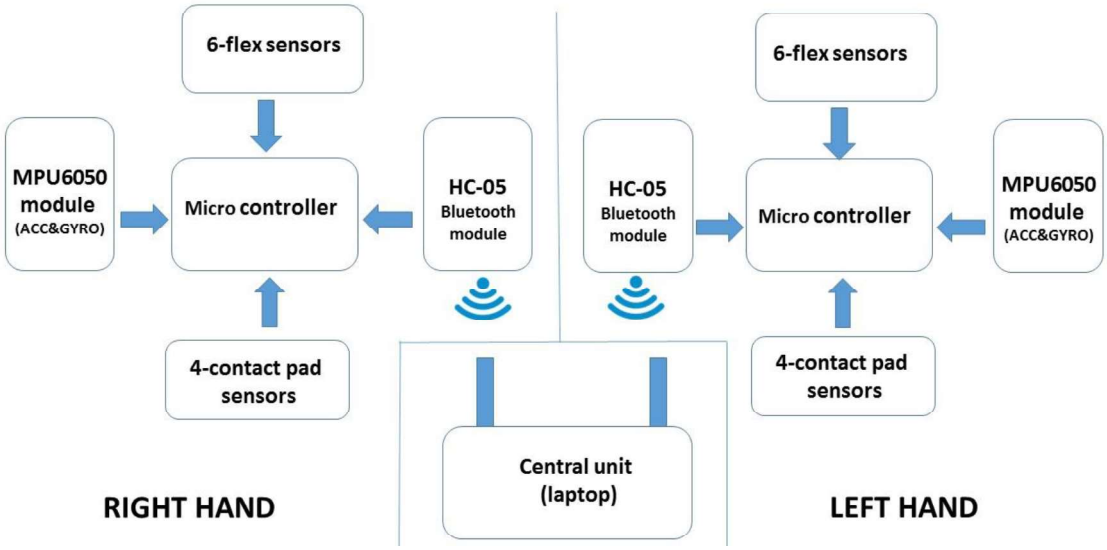


FIGURE 2.Block Diagram of Complete Design

After determining the price list of the smart glove components [9] as shown in TABLE 2, a comparison was held in terms of the total cost between the proposed design and the other existing types of smart gloves like (5DT glove, cyber glove, VHAND glove) [10-12]. It is clear that the total cost of the proposed design is less than 5% of the lowest price of commercial smart gloves. The proposed design is also able to cover all signs of the ARSL with only 12 sensors, so it is more than simple, and more reliable.

2.1 The Complete Interface Circuit

Depending on output types of flex sensors, contact pad sensors, an MPU6050 module and an HC-05 module, a complete interface circuits is designed to collect all sensors and modules' pin headers on one board, the schematic was designed on PROTEUS ISIS software program. The PCB layout as designed on PROTEUS ARES software program. A single layer board was carried out on milling machine, and the components were soldered, before the modules were fixed on it through the pin headers. The board is ready for software test as shown in Fig.3 after a successful electronic test on the board.

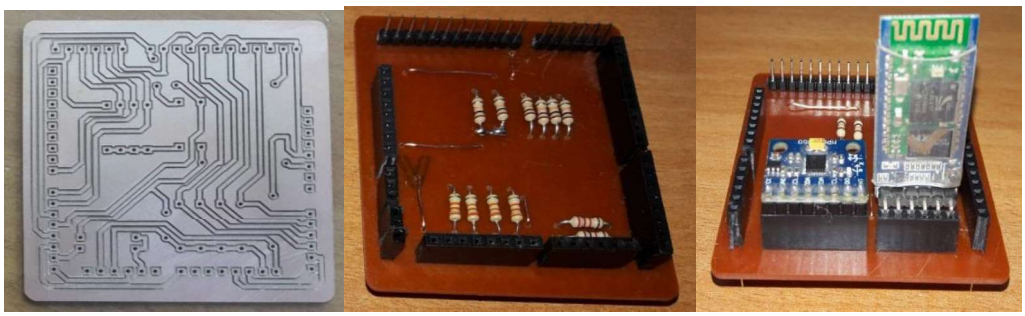


FIGURE 3.the stages of carrying out the interface circuit

2.2 Smart Glove ASLR Algorithm

After carrying out the interface circuit of the smart gloves, the code was written for testing the output of the sensors and modules on the Arduino Uno board by using Arduino IDE, I2C module is used for reading MPU6050 GYRO/ACCEL output data, ADC module is used for reading the flex sensor output, digital input pins are used for reading the contact pad sensors and UART is used for send all collected data to central unit, the sequence of the code is illustrated in the flowchart as shown in Fig.4.

TABLE 3: the order of data bits of contact pad sensors inside the first byte

D8	D7	D6	D5	D3	D2	D2	D1
NOT USED	NOT USED	Contact pad1	Contact pad1	Contact pad1	Contact pad1	FLEX1	FLEX6

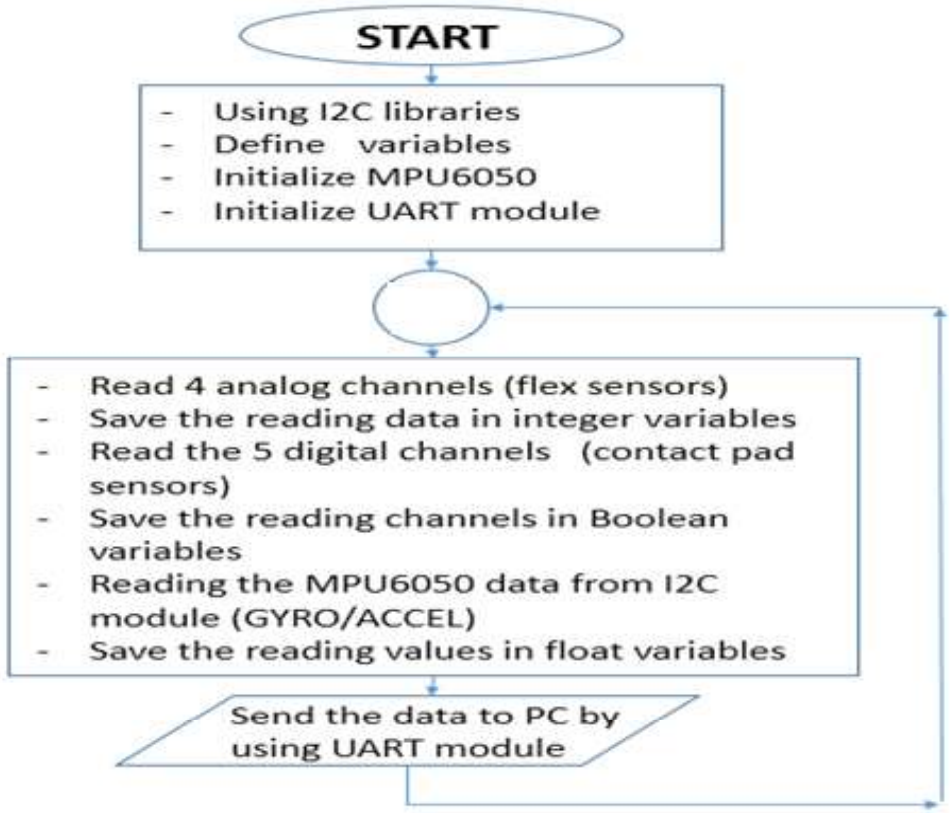


FIGURE 4.the flowchart of the code which is used for test the interface circuit

2.3 The Designed Data Packet

The aim of this algorithm is to minimize the transmission time to the central unit, the central unit is responsible for the analysis of the transmitted data from each glove and then predict the correct gesture. The glove's controller function is to Save the flex sensors readings into integer variables, Save the contact pad sensors readings into Boolean variables, Read the MPU6050 (GYR/ACC) data using I2c Bus, and save EULAR angles readings into float variables. After that sending all sensors and modules data which carries the information. However, data of all sensors and modules is 11-byte / stage (6 bytes for roll pitch yaw angles - 4 bytes for flex sensors – 1 byte for contact pads sensors). Such huge size of data is the Reason for the system speed reduction. In order to solve this issue, some analog data is digitalized to reduce the sent data up to 3-byte/stage depending on the author's previous analysis of ARSL [12]. Each byte of the 3 bytes has specific information as follows.

2.3.1 The first byte

The 1st byte carries the information of the contact pad sensors and the flex sensor of the thumb and the palm. For contact pad sensors, the logic high output indicates that two neighbour fingers are convergent, the logic low output indicates that two neighbour fingers are divergent. The flex sensor outputs of thumb and palm is digitalized to two probabilities. if the angle of bend greater than 45 degrees, the output will be logic high, otherwise the output will be logic low. Depending on this sequence, one bit is needed for representing the probabilities of one sensor, and the order of bits inside the byte data as shown in TABLE 3.

2.3.2 The second byte

The 2nd byte carries the information of the flex sensors of four fingers (pinky, ring, middle and index), these flex sensors analog outputs is digitalized to three probabilities (straight, half bend, complete bend) so the minimum number of bits are needed to represent three probabilities are two bits as shown in TABLE 4, the order

of the data bits of flex sensors in the second byte is illustrated in TABLE 5.

TABLE 4: the probabilities of flex sensors

00	Straight
01	Complete bend
10	Half bend
11	Not used

TABLE 5: the order of the data bits

D8	D7	D6	D5	D3	D2	D2	D1
Pinky finger		Ring finger		Middle finger		Index finger	

TABLE 6: the probabilities of orientation

00	-45<Angle<45
01	45<angle
10	-45>angle
11	Not used

TABLE 7: the order of the data bits

D8	D7	D6	D5	D3	D2	D2	D1
Not used	Not used	Yaw angle		Pitch angle		Roll angle	

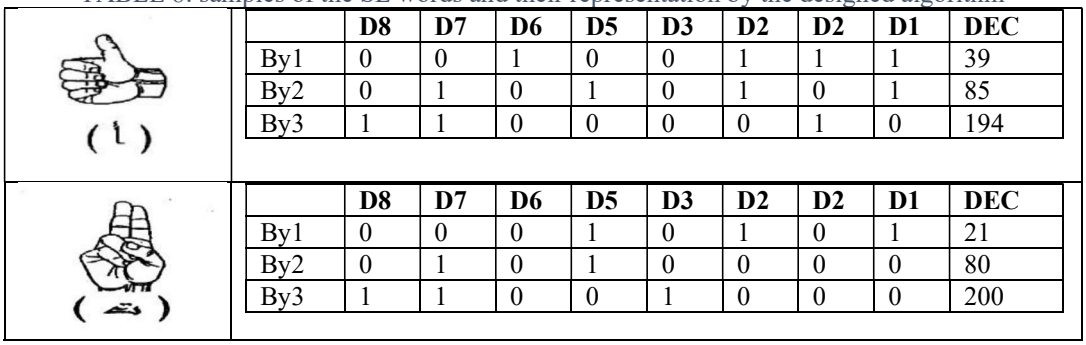
2.3.3 The third byte

The 3rd byte carries the digitalization of the MPU6050 Module (i.e. Gyro / ACC) data. Depending on the analysis of the ARSL, it has been found that there is no need for full orientation of the angles, so the value of the roll, pitch, and yaw angles are simplified to three probabilities per angle value as shown in TABLE 6, the order of the data bits of yaw pitch roll angles in the third byte is illustrated in TABLE 7

2.3.4 Case study for the algorism

After the glove data packet has been configured out, it is the time to examine the newly developed transmission scheme, TABLE 8 illustrates some samples of single stage single hand signs and shows the value of three bytes in binary and decimal format.

TABLE 8: samples of the SL words and their representation by the designed algorithm



	D8	D7	D6	D5	D3	D2	D2	D1	DEC
By1	0	0	1	0	0	1	1	1	39
By2	0	1	0	1	0	1	0	1	85
By3	1	1	0	0	0	0	1	0	194

	D8	D7	D6	D5	D3	D2	D2	D1	DEC
By1	0	0	0	1	0	1	0	1	21
By2	0	1	0	1	0	0	0	0	80
By3	1	1	0	0	1	0	0	0	200

2.4 The coding of the designed algorism

Depending on this algorism the Arduino code was written for the gloves of the two hands, this code consists of two main parts, the first part is the initialization code, initializing the MPU6050 module, initializing the HC-05 Bluetooth module, defining the variables which will be used in the looping processes, setting the maximum and minimum values of flex sensors and test the communication of MPU6050 with the controller.

The second part is the loop code, for reading the analog data from the flex sensors, reading the Boolean data from contact pad sensors, reading the MPU6050 from I2C communication bus, inserting the contact pad Boolean data in the first byte of the data packet, digitalizing the analog reads of flex sensors and insert it in the second byte of the data packet, digitalizing the MPU6050 angles and insert it in the third byte, and send the three byte by using the UART communication through HC-05 Bluetooth module as shown in the flowchart Fig.5.

2.4.1 The main features of the code

The maximum and minimum values of flex sensors is set in setup mode. Such feature is very important, if the experimental person is changed, the values of his finger bend will be set, also the MPU6050 and the zero orientation of the yaw pitch roll angle is initialized depend on the position of the experimental person. In the working mode the code reads the values of the sensors and digitalized it after that sends it as three bytes per one stage.

The sign language depending on the previous classification and the windows application which will be discussed in the next sections is divided into four groups, (single hand single stage - single hand multi-stage - double hand single stage - double hand multi-stage).

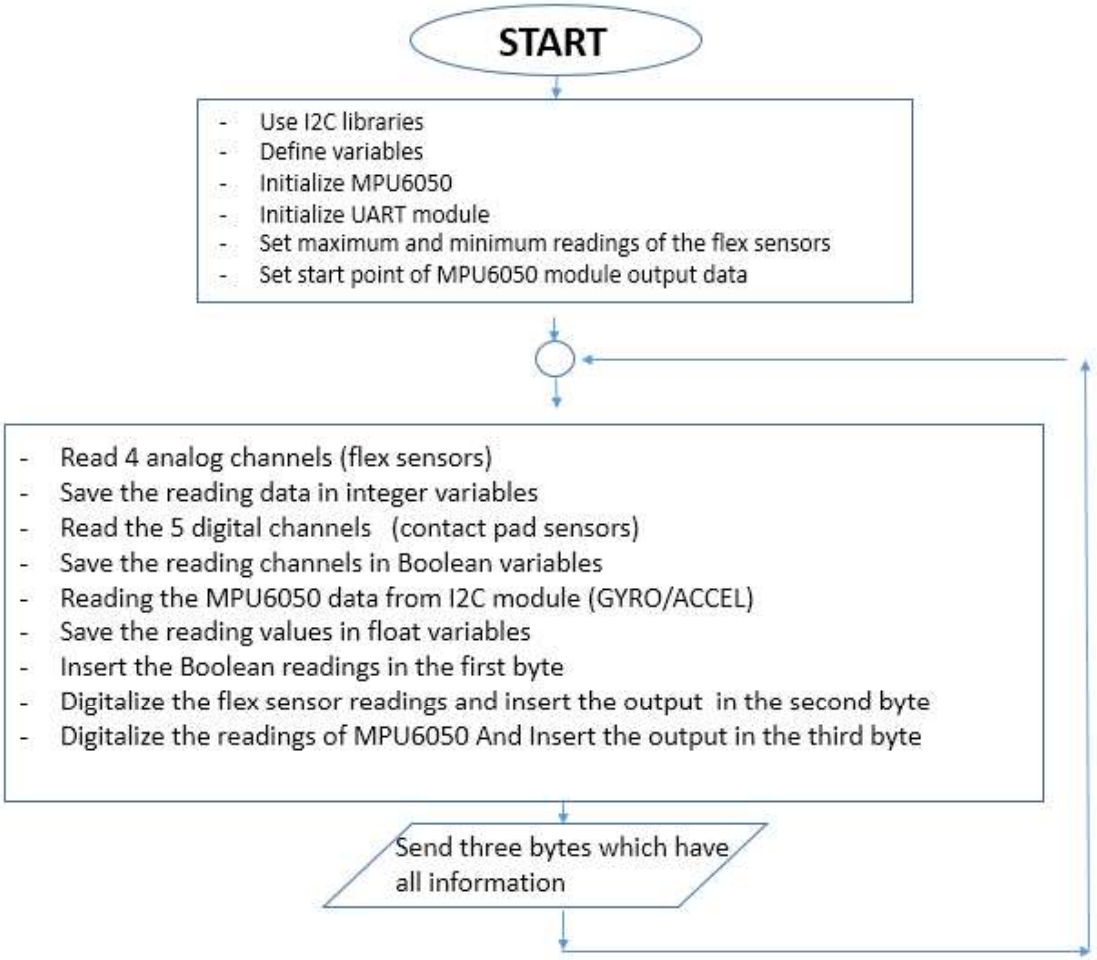


FIGURE 5.the flowchart of the code as built in the designed algorithm

3. WINDOWS APPLICATION FORM

The windows application forms were designed by VB.net to detect the relative words for the input sign, depending on the classifications of the sign language for the four groups, four window application forms were designed, one form per each group as shown in the next sections.

3.1 Single-hand Single-stage

This window application is divided into two parts; the upper part for setting up mode of the gloves, the lower part for main task (reading the three bytes from HC-05 Bluetooth module unit of the glove, searching about the matched word for the sign in the database and showing the image of the word).

The main features of this application form are; one serial port for receiving data from one glove, timer is used for setting the period of search, database of single stage single hand samples in Microsoft access sheet format is inserted in this form for searching about the data which is received through the serial port, and the software is created to identify the order of bytes because the bytes received serially without addresses. All details are illustrated in the flowchart as shown in Fig.6, this form was tested by using 28 words samples from Arabic SL and the results Show excellent performance, and pass 100%.

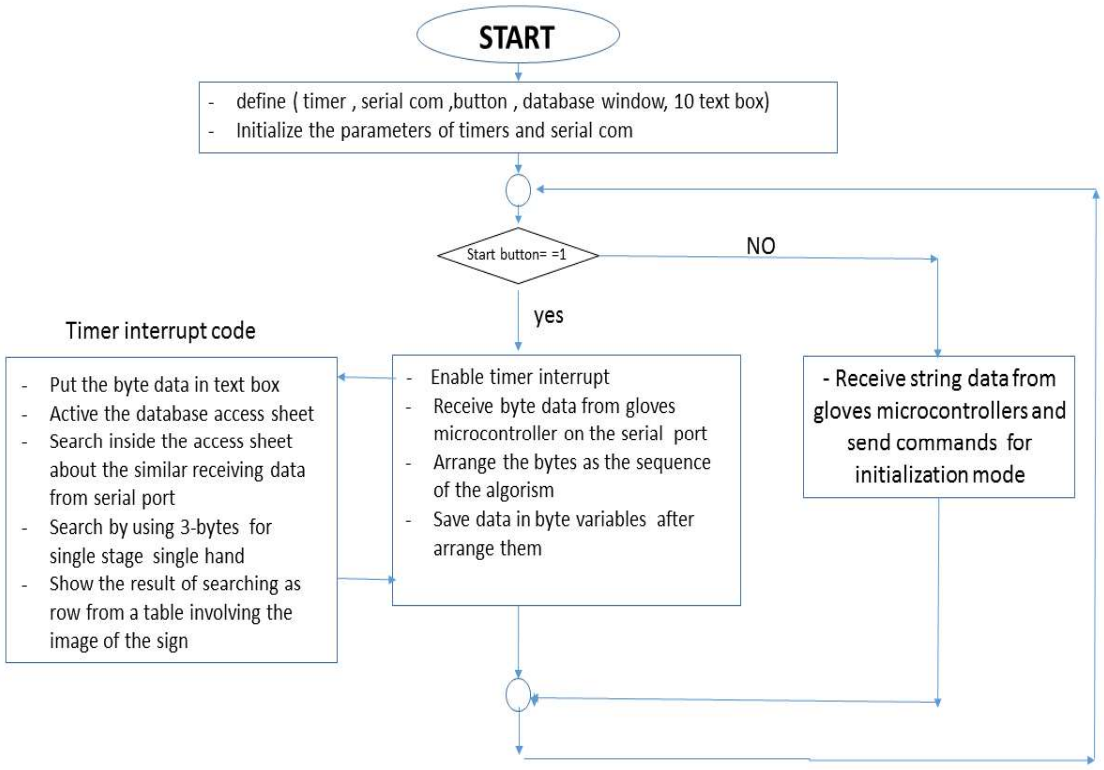


FIGURE 6. the flowchart of single hand single stage windows application form

3.2 Single-hand Multi-stage

This windows application form is divided into two parts; the upper part for setting up the mode of the gloves, the lower part for the main task (reading the three bytes from HC-05 Bluetooth module of the glove two times per one sign, searching about the matched word for the sign in the database and showing the image of the word), there is a modification over the first group procedure (the single hand single stage) by adding a variable working as a counter for the stage. The main features of this application form are; one serial port for receiving data from one glove, timer is used for setting the period of search, database of single stage single hand samples in Microsoft access sheet format is inserted in this form for searching about the data which is received through the serial port, and the software is created to identify the order of bytes because the bytes come serially without addresses. All details are illustrated in the flowchart as shown in Fig.7, this experiment is tested by using 20 samples and the result is 100% as shown in Fig.8.

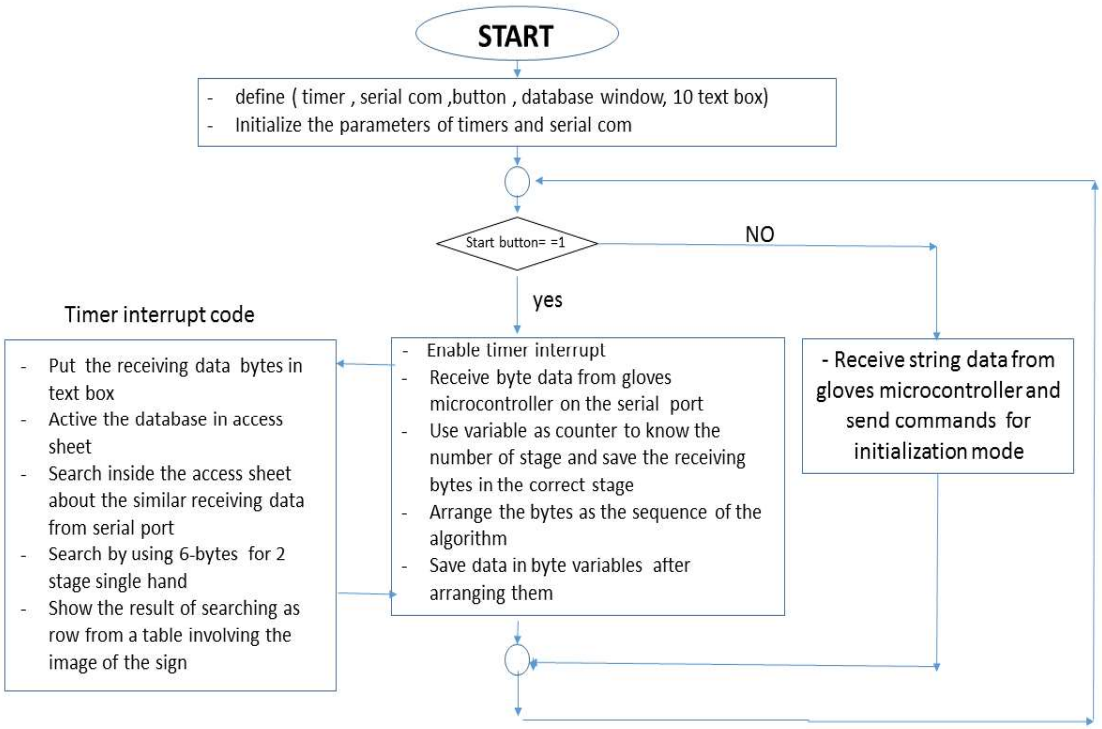


FIGURE 7. the flowchart of single hand multi-stage windows application form

FIGURE 8. A.the representation of "number 19" B. the representation of "number 100"

3.3 Double-hand Single-stage

This window application form is divided into two parts; the upper part for setting up mode of the gloves, the lower part for the main task (reading the three bytes per HC-05 Bluetooth module of the two gloves, searching about the matched word for the sign in the database and showing the image of the word) .The main features of this application form are; two serial port for receiving data from two gloves, timer is used for setting the period of search, database of single stage double hand samples in Microsoft access sheet format is inserted in this form for searching about the data which is received through the serial port, and the software is created to identify the order of bytes because the bytes come serially without addresses. BLUESOLEIL software is used to connect two HC-05 Bluetooth modules in the same central unit (laptop) to receive data from two gloves in the same time. All details are illustrated in the flowchart as shown in Fig.9, this experiment is tested and the result of 20 samples is 100% as shown in Fig.10.

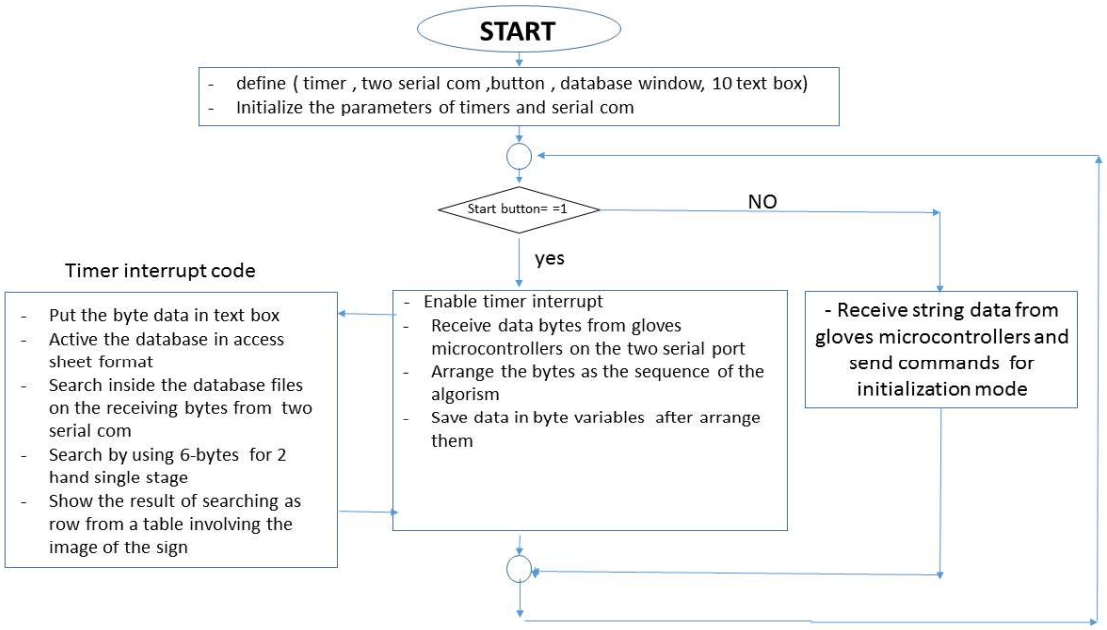


FIGURE 9. The Flowchart of Double Hand Single Stage Windows Application Form

FIGURE 10. A.the representation of "sandwich"

3.4 Double-hand Multi-stage (General Form)

This window application form is general form ,it can cover all previous classification, it is divided into two parts; the upper part for setting up mode of the gloves, the lower part for the main task (reading the three bytes per HC-05 Bluetooth module of the two gloves for two times, searching about the matched word for the sign in the database and showing the image of the word), for creating this form, a modification is done on the third group algorithm (the double hand single stage) like adding variable works as counter for the stage. The main features of this application form are; two serial port for receiving data from two gloves, timer is used for setting the period of search, database of single stage double hand samples in Microsoft access sheet format is inserted in this form for searching about the data which is received through the serial port, and the software is created to identify the order of bytes because the bytes come serially without addresses. BLUESOLEIL software is used to connect two HC-05 Bluetooth modules in the same central unit (laptop) to receive data from two gloves in the same time. This is a general algorithm, it's suitable for four groups by making some modifications in the format of database files of the groups only. All details are illustrated in the flowchart as shown in Fig.11 and the samples of database shown in TABLE 9, this experiment is tested and using 53 words database as shown in Fig.12 the result is 85% due to the synchronization problem of the Bluetooth receivers of two gloves.

TABLE 9: samples of the ASL words and its representation as Double Hand Multi-stage

	Right hand						Left hand					
	First stage			Second stage			First stage			Second stage		
	Byte1	Byte2	Byte3	Byte1	Byte2	Byte3	Byte1	Byte2	Byte3	Byte1	Byte2	Byte3
أ	39	85	194	39	85	194	15	0	198	15	0	198
ج	23	0	194	23	0	194	15	0	198	15	0	198
د	55	85	194	55	85	194	15	0	198	15	0	198
ذ	37	80	192	37	80	192	15	0	198	15	0	198
ابن	7	170	202	15	0	224	15	0	198	15	0	198
العائلة	3	2	197	3	2	196	3	2	198	3	2	200
الرضيع	7	0	224	7	0	224	7	0	208	7	0	208
ملكى	7	0	202	7	0	202	15	0	198	15	0	198
انت	51	84	194	51	84	194	15	0	198	15	0	198
هذا	51	84	196	51	84	196	15	0	208	15	0	208

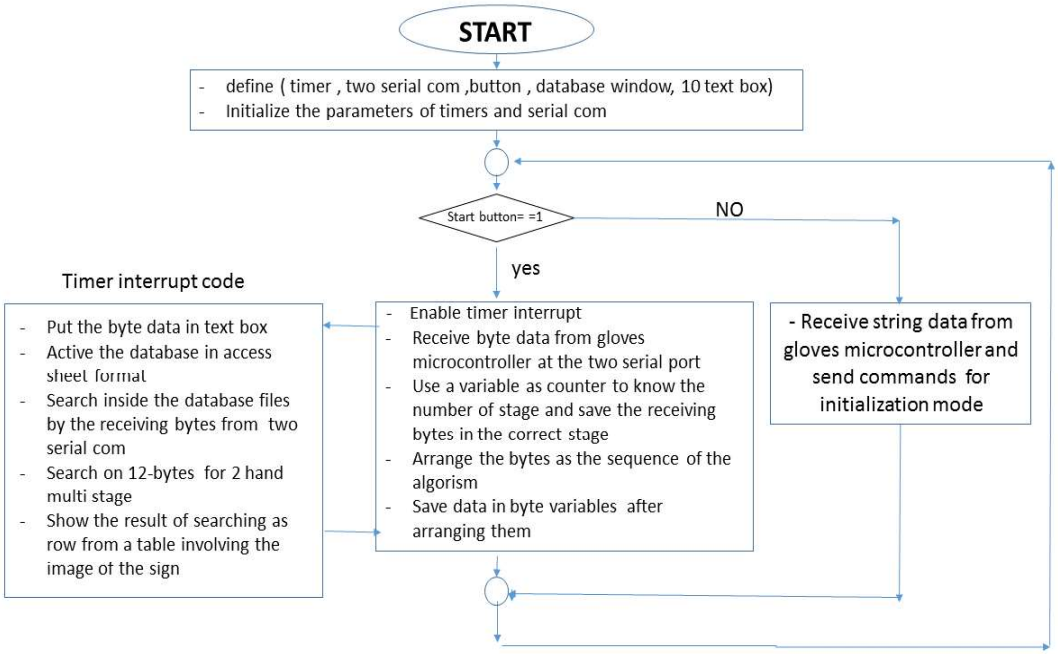


FIGURE 11. The Flowchart of Double Hand Multi-Stage Windows Application Form

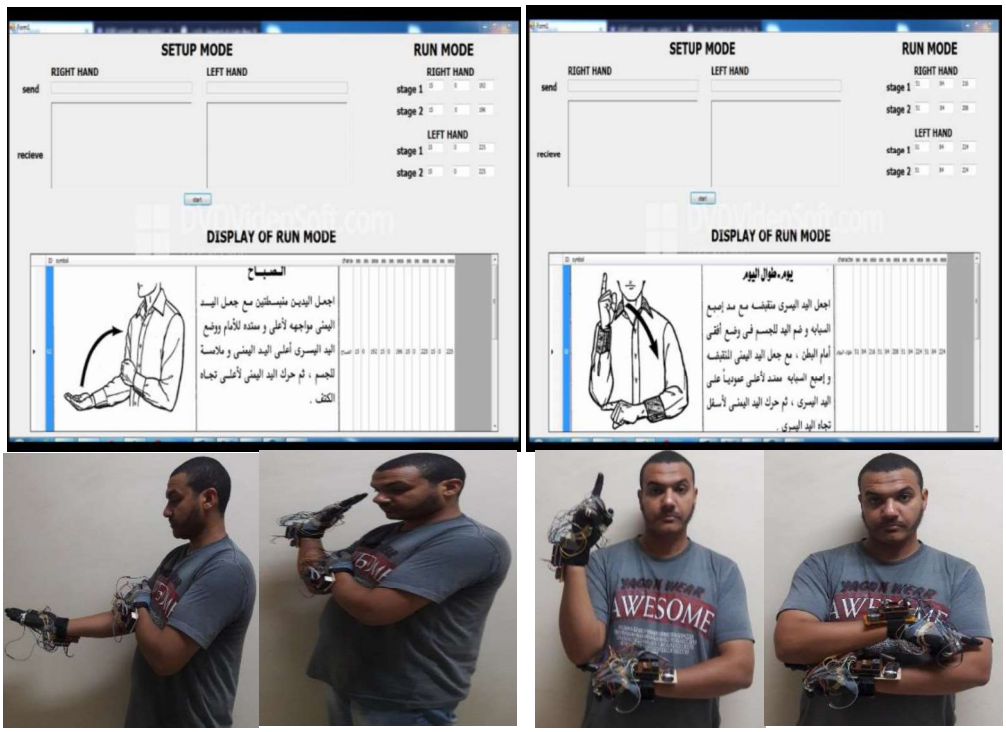


FIGURE 12 .A.the representation of "lighter" B. the representation of "Day"

4. CONCLUSION

After showing the work of this paper, the result of the Arabic SL words level by using the embedded system which is created depends on the analysis of Arabic SL words level, by using 53 words as a sample from all Arabic SL words level will be mentioned in the following points with the reasons.

1- (Single hand single stage) is achieved by 100%.
2- (Double hands single stage) is achieved by 100%.
3- (Single hand double stage) is achieved by 90%.
The reasons:
- The windows application form is designed depending on the timer interrupt , if there is a delay from the user in sending the second stage , the code will consider the first stage is same as the second stage and the result will not correct

4- (Double hands multi-stage) is achieved by 85%
The reasons:
- The system used two separated Bluetooth modules for transmitting data from the two gloves to the central unit, that's mean there is no synchronization between two hands, also this technology needs addressing, and this is the reason of delaying the sent data.
- The windows application form is designed depending on the timer interrupt. If there is a delay from the user in sending the second stage, the code will consider the first stage is same as the second stage, or there is a delay between sent data from two hands, the result will not correct.

In the future work, the system will use WIFI technology rather than Bluetooth technology to overcome on the non-synchronization and the delay problems .the windows application form will be designed depending on motion interrupt of the hand rather than timer interrupt to solve the problem of knowing the order of stage.

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